TITLE: Improvement in Heat Transfer Rate and Dynamics of Shrouded Fanned Radiator System

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ABSTRACT

This presented research presents the design and development of a fanned radiator system in order to increase the heat transfer rate and to make the radiator system dynamically stable (like reduction of vibrations in fan module) as compared to existing simple, geometrically same fan and simple radiator having same area of heat transfer .The experiments were conducted on a test set up which is fabricated and mounted on a steel pipe structure. Three modifications are done on the existing simple fanned radiator systems which include, 1) Use of louvered fins. 2) Use of nano particles(TiO2) in the fluid being used. 3)Shrouding of the fan 4) Cutting profiles on a fan blade leading edge using the biomimicry of whale tubercles.The analysis of the designed components were done using solidworks software as a tool. The experiments were carried using temperature sensors, water pump, and in similar ambient conditions. The simulation of fan was done usingsolidworks. Various parameters were considered in the experiment in order to validate the design and to achieve the required results like temperature difference, time required for the fluid (at particular fluid flow rate) to gain the ambient temperature, amplitude of vibrations induced in the system due to fan. The results show that the heat transfer rate increased tremendously. Also the vibration amplitude of the system was reduced. It is found that the improvement in performance of radiator gets highly affected by the turbulence created in the radiator fins so that for the same capacity of radiator we can design a relatively low surface area radiator and it will reduce material cost, size of radiator and hence it will occupy less space. The shrouding and bio mimic shape of fan blades helped to reduce vibrations and drag force hence helping to increase efficiency of the fan.

Keywords*: louvered fins, shroud,biomimicry, tubercles, nanoparticles, (TiO2) etc.*

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1. INTRODUCTION:

Radiators are used to transfer thermal energy from one medium to another for the purpose of cooling. Research is being carried out for several decades now, in improving the performance of the radiators, which are very compact and can be used in automobile industry. Also the research is going on in order to reduce the noise and overall cost of the radiators with increase in heat transfer rate. These compact radiators have fins, louvers and tubes.

The experimental setup through which we have obtained increase in heat transfer rate of radiator consist the following things:

i. Radiator with louvered fins
ii. Coolant Reservoir
iii. Shrouded fan having biomimicry shaped blades
iv. Nano-particles
v. Pump
vi. Motor
vii. Water based Glycol

1.1 Radiator with louvered fins :

Radiator are also called as heat exchanger with the purpose of takeout heat from source[4]. Here heat is transmitting through coolant liquid medium to atmosphere. It consists of core, top and bottom tank. Core is designed with two sets of passageway, one set of tube as well as fin. Liquid coolant flows inside the fins as soon as air gets flow its outer surfaces. The heat presents in the fluid which is supplied via. Source is absorbed by the coolant. The nano-particles present in the coolant increases the heat carrying capacity of the fluid and further it is carried via radiator then exchange it with atmosphere with help of fan.
Whereas, the radiator which we have used for the experiment have louvered fins. The purpose behind using the louvered fin is to break the boundary layer which causes the flow become turbulent that results into increase in convective heat transfer coefficient i.e. h.

1.2 Shrouded fan:

The axial flow fan is extensively used in many engineering applications. The axial fans are very adaptable and that is why they are extensively used in the industry for the cooling purpose and moving the toxic gases in the petrochemical industry. The need of using compact fans in the automobile industry is because of the increasing demand for the low degree of compactness and low weight systems. The extended use of axial flow fans for fluid movement and heat transfer has resulted in detailed research into the performance attributes of many designs.
In case of the fan that we have used and designed for this experiment have a tip to tip connected shroud which makes the fan blades stiffer and tip vibrations are reduces significantly. That results reduce in the noise of the fan.

1.3 Nano Particles :

Nano fluids is a fluid having non sized solid particles, normally particle size less than 100 nm, disperse in the convectional based fluid water, mineral oil, ethylene glycol. This tremendously enhance the heat transfer characteristics (and little penalty in pressure drop) of original fluid. The advanced technology nowadays is having great potential to increase the thermal properties of fluids being used in the radiators.
The nano-particles which we have used in this experiment is TiO_2. The reason behind using the nano-particles is to get higher heat transfer rate.

2. Design and Analysis:

The assembly components which are designed for the betterment of results are as follows:

i. Louvered fins
ii. Shrouded fan
iii. Hub of fan

2.1 louvered finsGeometry:

The following table and fig. gives an idea about the louvers which are used for optimized results:

Number	**Fin Pitch F_p (mm)**	**Louver Pitch L_p (mm)**	**Louver angle L_a(degree)**	**Tube Pitch T_p (mm)**	**Number of tubes n**	**Hydraulic diameter d_h (mm)**
1	2.02	1.4	22^o	11	32	3.35

Table-1: Details about the Louvered fins

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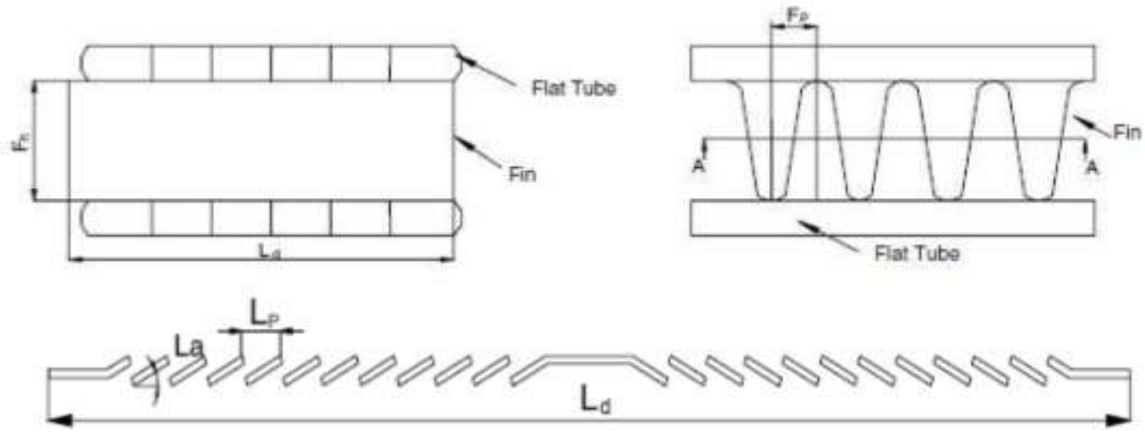

Fig-1: Fin Terminology

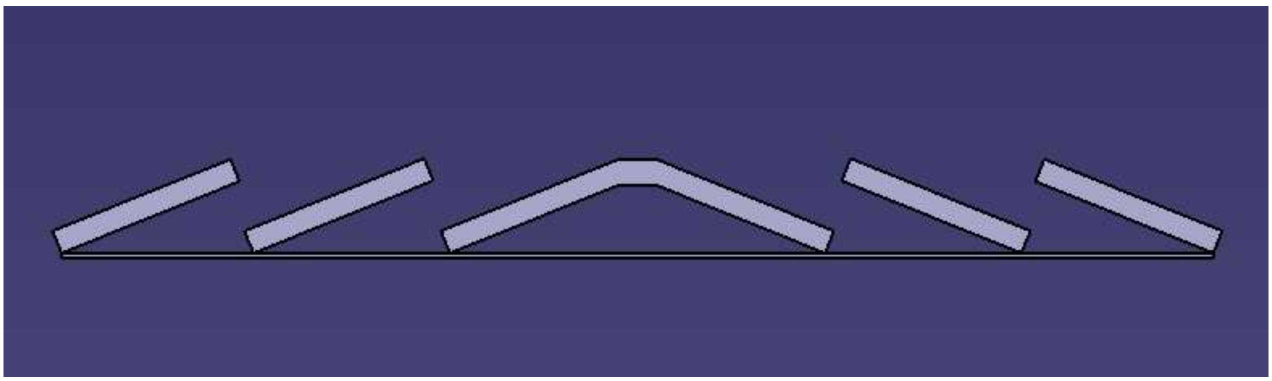

Fig-2: CAD model of Louvers

2.2 Shrouded Fan:

Following factors are considered while designing the shrouded fan:

1. Air flow volume should be higher
2. The noise level must be reduced.

Fig-3: CAD Model of shrouded Fan

Sr. No.	Parameter	Value
1	Minimum Dia. Of Hub	0.15 m
2	Min. dia. Of Wheel	0.30 m
3	Hub Tip Ratio	1:2
4	No. Blades	6
5	Blades Spacing	0.1570 m
6	Tip Speed	267.0353 rpm

Table-2: Details of shrouded fan

2.2.2 Flow simulation of fan :

Air velocity range obtained at radiator position between the range of 39 to 58 m/s

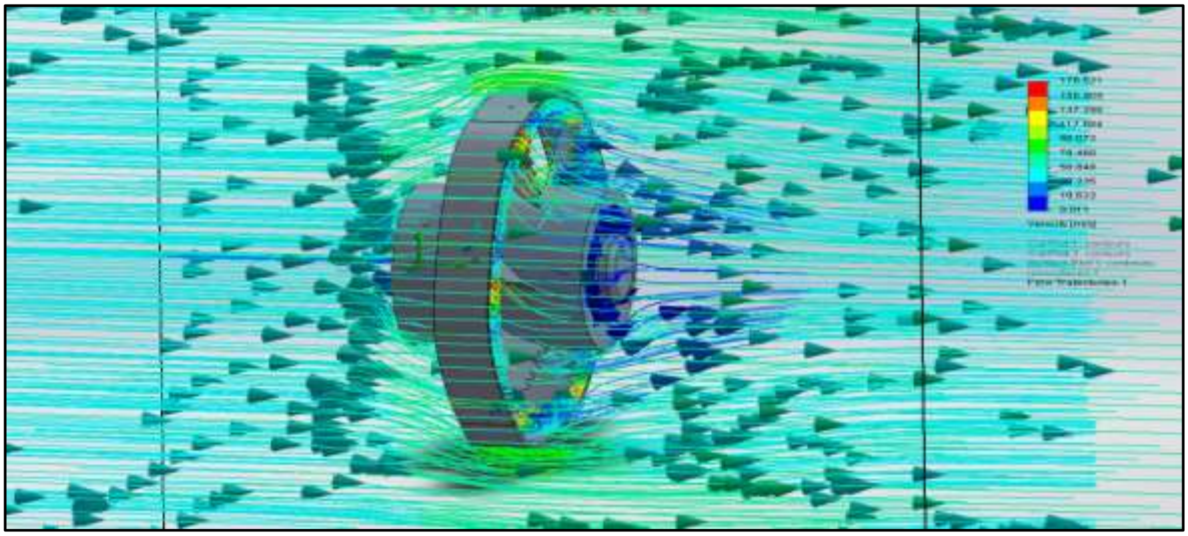

Fig-4: Velocity Distribution

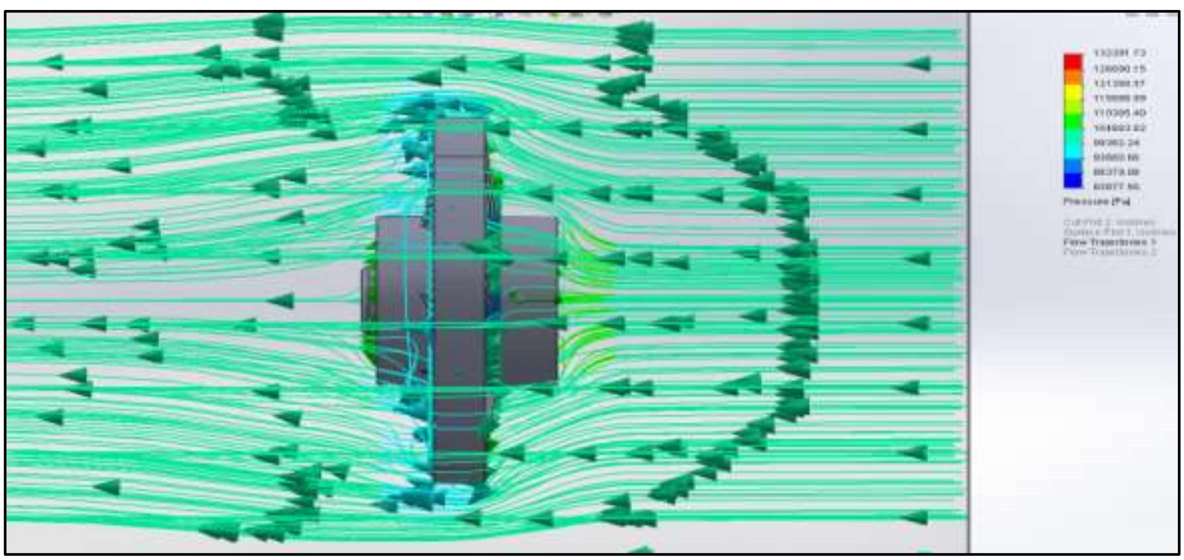

Fig-5: Pressure Distribution

3. Experimental study:

3.1: Experimental setup: The given below image is actual experimental setup which was used. The setup has a pump for pumping the fluid, a reservoir that contain fluid. Two temperature sensors were used for taking readings of temperature instantaneously.

3.2: Procedure: The experiment was conducted firstly using simple fin and simple fan and readings were taken for the temperature after every 1 minute for the same ambient conditions. Then the same procedure was carried out by using louvered fin radiator and modified fan and corresponding readings were taken.
Also for vibration measurement, a accelerometer is placed on the structure at same place and readings are taken for both cases.

Sr. No.	Parameter	Value
1	Ambient temperature	35^0C
2	Amount of fluid	10 litres
3	Initial temperature	44^0C
4	Amount of TiO_2 added	20 gms

Fig-6: Actual experiment setup

Table-3

4. Results: Given below fig-7 is the graph of temperature Vs time in minutes for both the radiators. Where red colour indicates the graph of simple radiator and purple colour indicates graph of modified radiator system. Also fig-8, 9 are the results of vibrations for the simple and modified fan.

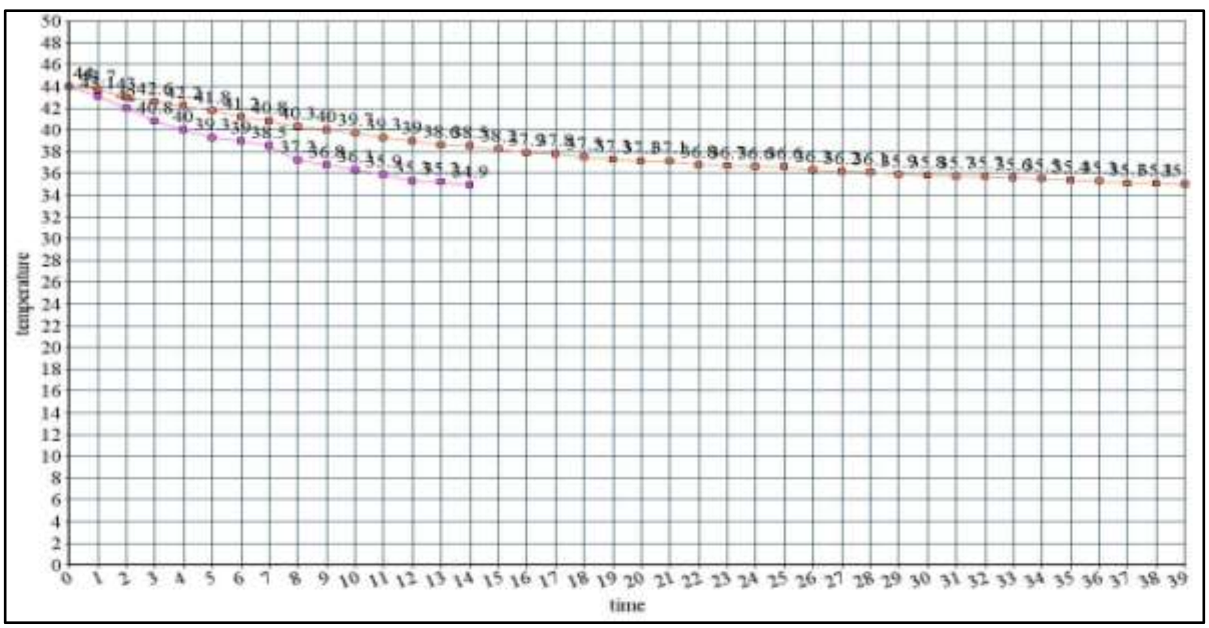

Fig-7: Comparison of both radiator systems

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4.1 Result Based on Graph:

Unit less numbers used depending upon the medium of fluid are as follows:

1. Reynold's number: $Re = \frac{\rho * V * L}{\gamma}$
2. Prandtl number = 0.7
3. Nusselt's number = $0.036 * Re^{0.8} * Pr^{0.33}$
4. Nusselt number= Nu = $\frac{h * L}{K}$
5. Thermal Conductivity of aluminium i.e. $K_{aluminium}$ = 237 W/mk
6. Total Area of Heat Transfer = 0.078 m^2
7. Time for which the fluid was circulated= 14 min.

Sr. No.	Radiator which is used	Convective heat transfer coefficient (W/m^2K)	Heat Transfer Rate (kW)	% increase
1	Simple Radiator	$964*10^3$	413.55 kW	63.63 %
2	Modified Radiator	$964*10^3$	676.728 kW	

Table-4: Comparison of heat transfer rates

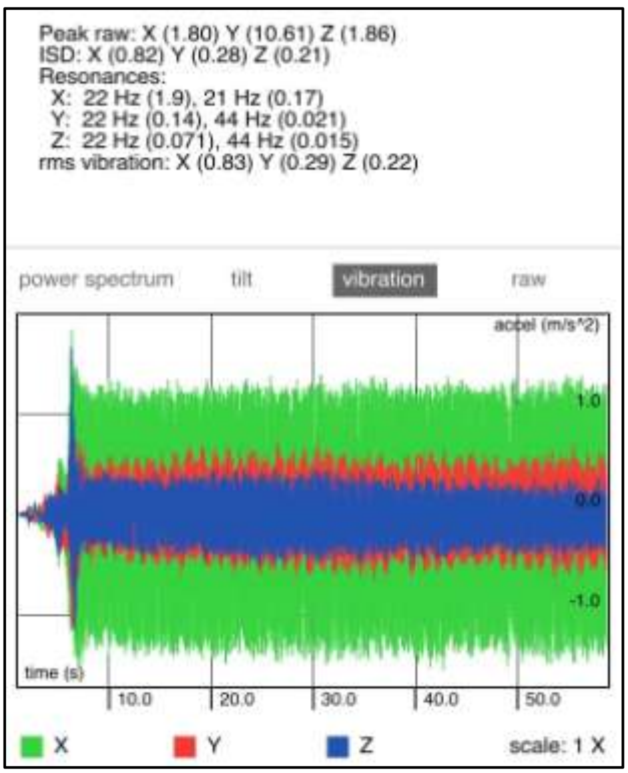

Fig-8: Vibrations due to modified fan.

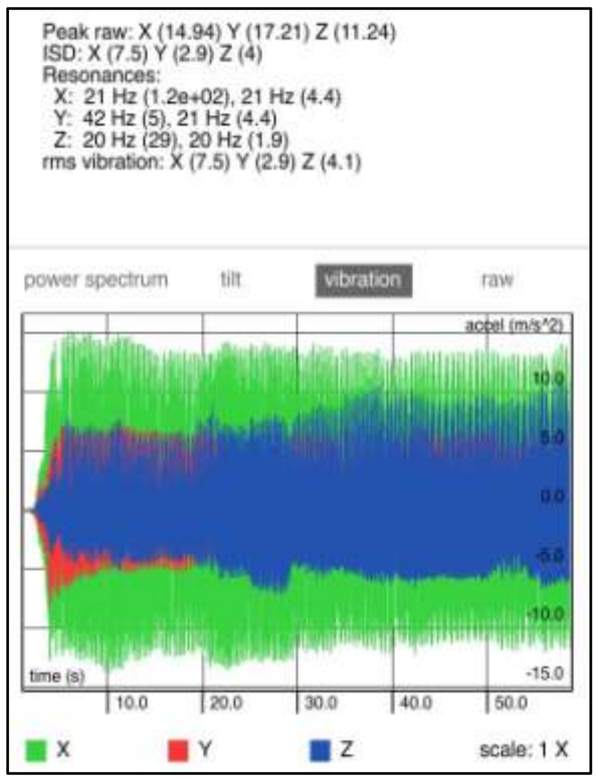

Fig-9: Vibrations due to simple fan.

From above graphs of acceleration Vs time, it is observed that for simple fan, the acceleration in Z direction is between 5-10 m/s^2. And for modified fan, the acceleration is between 0-1 m/s^2. Which is a drastic change.

5. CONCLUSION

From the above results obtained, we can conclude that the addition of TiO_2 nanoparticles increases the coefficient of thermal conduction and use of louvered fins at an angle of 22^0 breaks the boundary layer and makes the flow turbulent hence increases coefficient of convection heat transfer as compared to simple fins which results in streamlined flow.

The use of louvered fins and addition of nanoparticles increases rate of heat transfer by 63%.

Which means we can design radiator of same heat transfer capacity having a low area, which results in a compact, low weight, low cost radiator unit for same function.

Also the modifications done in the fan results decrease in vibrations. The acceleration decreased by 92%. It means that the vibrations are reduced by significant amount. The area of tip of blade which vibrates and produces maximum vibrations are reduced by providing a shroud connected tip to tip and makes the system more stable.

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REFERENCES

[1] D Govindaraj,” Effective selection methodology for a louvered fin heat exchanger using thermal resistance and number of transfer units method”, SAE India, 2011.

[2] L. K. Goldenstein , D.W. Radford And P.A. Fitzhorn,” The Effect Of Nanoparticle Additions On The Heat Capacity Of Common Coolants”, SAE, 2002.

[3] Hidetake Ota, Katayama Yuichi , Yokoyama Hiroshi and Osawa Yukio,” Development of High Efficient Radiator Cooling Fan for Automotive Application”, SAE, 2013.

[4] Gifford N. L., Hunt A. G., Savory E., Martinuzzi R. J.,” Experimental Study of Low-Pressure Automotive Cooling Fan Aerodynamics Under Blocked Conditions”, CSME, 2006

[5] Sam Weitzman and Ann Lambert.” More Efficient Helicopter Blades Based on Whale Tubercles”, Journal of Emerging Investigators, Dec 22, 2013.

[6] https://en.wikipedia.org/wiki/Radiator.